CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Section 6313(a)(6)(A) of 42 U.S.C. requires the DOE to set forth energy conservation standards that are technologically feasible and economically justified and would result in significant additional energy conservation. This chapter provides a description of the general analytical framework that the Department uses in developing such standards, and in particular, standards for commercial unitary air conditioners and heat pumps. Essentially, the analytical framework is a description of the methodology, the analytical tools, and relationships among the various analyses that are part of this rulemaking. For example, the methodology that addresses the statutory requirement for economic justification includes analyses of life-cycle cost; economic impact on manufacturers and users; national benefits; impacts, if any, on utility; and impacts, if any, from lessening competition.

Figure 2.1.1 summarizes the analytical components of the standards-setting process. The focus of this figure is the center column, identified as "analysis." The columns labeled "key inputs" and "key outputs" show how the analyses fit into the rulemaking process, and how the analyses relate to each other. Key inputs are the types of data and information that the analyses require. Some key inputs exist in public databases; DOE collects other inputs from stakeholders or persons with special knowledge. Key outputs are analytical results that feed directly into the standards-setting process. Dotted lines connecting analyses show types of information that feed from one analysis to another.

The analyses performed in the Advance Notice of Proposed Rulemaking (ANOPR) stage and reported in this technical support document (TSD) include:

- A market and technology assessment to characterize the relevant equipment markets and existing technology options, including prototype designs.

- A screening analysis to review each technology option and determine if it is practicable to manufacture, install, and service, would adversely affect equipment utility or equipment availability, or would have adverse impacts on health and safety.

- An engineering analysis to develop cost/efficiency relationships that show the manufacturer's cost of achieving increased efficiency.

- A building energy use and end-use load characterization analysis to determine the annual energy use and hourly power consumption characteristics of commercial unitary air conditioners in the commercial building stock.

- A life-cycle cost (LCC) and payback period (PBP) analysis to calculate, at the customer level, the discounted savings in operating costs (less maintenance and repair costs) throughout the estimated average life of the covered equipment, compared to any increase in the installed cost for the equipment likely to result directly from the imposition of the standard.

- A national impact analysis to assess the aggregate impacts at the national level of the net present value (NPV) of total consumer life-cycle cost and national energy savings.

The analyses to be performed in the subsequent Notice of Proposed Rulemaking (NOPR) stage include those listed below. In addition, the Department re-analyzes the work done in the ANOPR stage.

- A life-cycle cost sub-group analysis to evaluate variations in commercial building characteristics (e.g., energy prices, equipment use behavior, installation costs) that might cause a standard to impact particular customer sub-populations, such as specific building occupant types (e.g., office or retail building occupants), differently than the overall population.

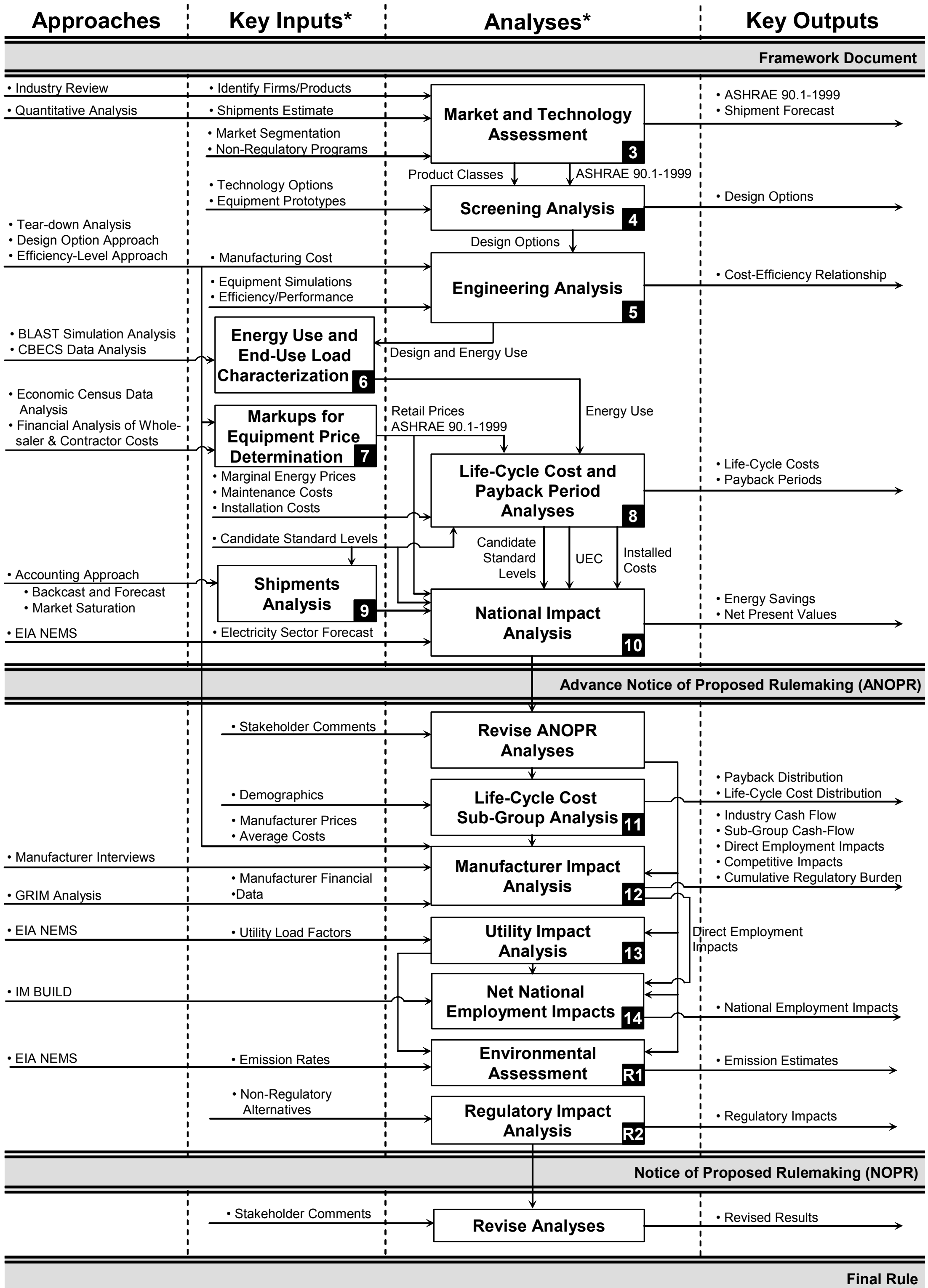
- A manufacturer impact analysis to estimate the financial impact of standards on manufacturers and to calculate impacts on competition, employment, and manufacturing capacity.

- A utility impact analysis to estimate the effects of proposed standards on electric utilities.

- An environmental assessment to provide estimates of changes in emissions of pollutants (nitrogen oxides and carbon dioxide).

- An employment impact analysis to assess the aggregate impacts on national employment.

- A regulatory impact analysis to present major alternatives to proposed standards that could achieve substantially the same regulatory goal at a lower cost.



* Dark boxes indicate TSD chapters and reports.

Figure 2.1.1 Flow Diagram of Analysis for the Commercial Unitary Air Conditioner and Heat Pump Rulemaking Process

2.2 BACKGROUND

As described in Chapter 1, the Process Rule outlined procedural improvements to the standards rulemaking process which included a review of the following elements used in the rulemaking process: (1) economic models; (2) analytical tools; (3) methodologies; (4) non-regulatory approaches; and (5) prioritization of future rules. See appendix A to subpart C of Title 10 Code of Federal Regulations Part 430 (10 CFR Part 430). Also, the Process Rule required the Department to take into account uncertainty and variability by doing scenario or probability analyses. Appendix K of this TSD provides a detailed discussion of variability and uncertainty.

The Department developed the analytical framework for the commercial unitary air conditioner and heat pump rulemaking under the Process Rule. The Department presented this analytical framework to stakeholders during the commercial unitary air conditioner and heat pump workshop held on October 1, 2001. The following sections provide a general description of the different analytical components of the rulemaking framework.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant product markets and existing technology options, including prototype designs.

2.3.1 Market Assessment

When initiating a standards rulemaking, the Department develops information on the present and past industry structure and market characteristics for the equipment concerned. This activity assesses the industry and equipment both quantitatively and qualitatively, based on publicly available information. As such, the Department addresses the following matters: (1) manufacturer market share and characteristics; (2) trends in the number of manufacturing firms; (3) the financial situation of manufacturers; (4) existing, non-regulatory, efficiency improvement initiatives; and (5) trends in product characteristics and retail markets. This information serves as resource material throughout the rulemaking.

The Department reviewed existing literature and interviewed manufacturers to get an overall picture of the commercial unitary air conditioner and heat pump market in the United States. Industry publications and trade journals, government agencies, and trade organizations provided the bulk of the information, including: (1) manufacturer market share; (2) shipments by capacity and efficiency level; (3) price distribution; (4) market saturation; and (5) distribution trends. The appropriate sections of this ANOPR describe the resulting information as DOE used it in the analysis.

The Department has used and will use the most reliable and accurate data available at the time of each analysis in this rulemaking. All data will be available for public review. The Department welcomes and will consider any recommendations of additional data.

2.3.2 Technology Assessment

The Department typically uses information relating to existing and past technology options and prototype designs as inputs to determine what technologies manufacturers use to attain higher energy-efficiency levels. In consultation with interested parties, the Department develops a list of technologies for consideration. Initially, these technologies encompass all those it believes are technologically feasible.

The Department developed its list of technologically feasible design options from consultation with manufacturers of components and systems, and from trade publications and technical papers. Since many options for improving product efficiency are available in existing equipment, product literature and direct examination provided additional information.

2.3.3 Equipment Classes

The Department divided equipment types into classes according to the following criteria: (a) the type of energy used; (b) capacity; and (c) performance-related features that affect consumer utility or efficiency. Different energy efficiency standards apply to different equipment classes. The Department defined these equipment classes using information from discussions with manufacturers of commercial unitary air conditioners and heat pumps, trade associations, and other interested parties.

For purposes of this rulemaking, DOE defined four equipment sub-categories for its analyses: (1) single package and split system unitary air conditioners with a cooling capacity of ≥65,000 Btu/h and <135,000 Btu/h; (2) single package and split system unitary heat pumps with a cooling capacity of ≥65,000 Btu/h and <135,000 Btu/h; (3) single package and split system unitary air conditioners with a cooling capacity of ≥135,000 Btu/h and <240,000 Btu/h; and (4) single package and split system unitary heat pumps with a cooling capacity of ≥135,000 Btu/h and <240,000 Btu/h.

Chapter 3 identifies two other niche equipment classes: (1) single package vertical units (SPVU), which are single package unitary air conditioning equipment that have been designed with the components oriented vertically rather than horizontally; and (2) single package or split system equipment for specialized applications. The latter equipment generally has customer-specific features on a baseline model. For example, single package or split system air conditioning units provide very precise climate control, both in temperature and in humidity ratio, for applications like computer rooms, and specialized laboratory or hospital applications. For reasons to do with design and test procedure considerations, the Department will not address these two niche product classes in this rulemaking.

As stated in Chapter 1, this ANOPR TSD covers only the analyses of the two non-niche equipment classes of unitary air conditioners (i.e., units with cooling capacity of ≥65,000 Btu/h and <135,000 Btu/h and units with cooling capacity of ≥135,000 Btu/h and <240,000 Btu/h). The Department chose not to collect the necessary data for conducting the detailed technical analyses for unitary heat pumps. Instead, it proposes to establish the minimum heat pump energy efficiency ratio (EER) and coefficient of performance (COP) levels using a method similar to the one the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE)/Illuminating Engineering Society of North America (IESNA) Standards Committee 90.1 employs in its determination of the minimum efficiency levels. It is the Department's understanding that ASHRAE determined the minimum efficiency level for air conditioners and then agreed to a minimum heat pump EER after consulting with the Air-Conditioning and Refrigeration Institute (ARI). The minimum heat efficiency of the heat pump, defined by the heat pump COP, was then set to correspond to the minimum EER using data provided by ARI that correlated the heat pump COP to the heat pump EER. The Department, in its ANOPR, is requesting comments on the need for conducting an analysis specific to the equipment classes that it has not analyzed in this TSD.

2.4 SCREENING ANALYSIS

The screening analysis examines various technologies as to whether they: (a) are technologically feasible; (b) are practicable to manufacture, install, and service; (c) have an adverse impact on equipment utility or availability; and (d) have adverse impacts on health and safety. As previously described in the section describing the technology assessment, DOE develops an initial list of efficiency enhancement options from the technologies identified in the technology assessment. Then the Department, in consultation with interested parties, reviews the list to determine if these options are practicable to manufacture, install, and service, would adversely affect equipment utility or availability, or would have adverse impacts on health and safety. In the engineering analysis, the Department further considers efficiency enhancement options that remain after the screening process.

2.4.1 Technology Screening

As described in Chapter 4, the Department grouped technologies into the following categories: (1) emerging technologies, which are currently not available on the commercial market but are being examined in the laboratory as possible means to enhance efficiency; and (2) commercially available technologies that are used to improve the EER (nominal full load) rating under DOE's test conditions.

Because the energy descriptor for commercial unitary air conditioners and air-source heat pumps is an EER, and the test procedure does not account for part-load operation, DOE has not included a part load performance descriptor in this analysis. Therefore, only those design options that improve the EER (nominal full-load) rating were considered viable for review. Further, because many of these technologies already have been incorporated in commercially available designs, the design options viable for review and those actually considered in the engineering analysis were: increasing evaporator and condenser coil area (keeping coil rows the same), and increasing coil rows (keeping face area the same).

2.5 ENGINEERING ANALYSIS

As presented in Chapter 5, the engineering analysis establishes the relationship between the cost and efficiency of commercial unitary air conditioners and heat pumps. This relationship serves as the basis for cost/benefit calculations in terms of individual consumers, manufacturers, and the nation. In sum, the engineering analysis identifies representative baseline equipment, develops a the bill of materials and determines subsequent costs, constructs the industry cost/efficiency curves, and evaluates the impact of using an alternative refrigerants on the cost/efficiency relationship of certain commercial air conditioners and heat pumps.

2.5.1 Baseline Equipment

To analyze design options for energy-efficiency improvements, the Department defined a baseline unit. Section 6313(a)(6)(A) of 42 U.S.C. requires DOE to establish an amended uniform national standard for commercial unitary air conditioners and heat pumps at the minimum level specified in ASHRAE/IESNA Standard 90.1-1999, unless DOE determines, through a rulemaking supported by clear and convincing evidence, that a more stringent standard is technologically feasible and economically justified and would result in significant additional energy conservation. Because the Department is not able to consider levels lower than that of the most recent ASHRAE/IESNA Standard 90.1, the Department considers the baseline efficiency to be the minimum level specified in ASHRAE/IESNA Standard 90.1-1999.

Therefore, DOE selected the ASHRAE/IESNA Standard 90.1-1999 levels as the baseline efficiency levels for the present rulemaking. Table 2.5.1 presents the ASHRAE/IESNA Standard 90.1-1999 minimum efficiency levels for the equipment covered in this standards rulemaking.

Table 2.5.1 ASHRAE/IESNA Standard 90.1-1999 Minimum EER requirements for Unitary Equipment

Equipment Type	Size Category	Heating Section Type	Sub-Category	Minimum Efficiency
Air Conditioners, Air Cooled	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.3 EER
		All Other	Split System and Single Package	10.1 EER
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER
		All Other	Split System and Single Package	9.5 EER
Heat Pumps, Air Cooled (Cooling Mode)	≥65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.1 EER
		All Other	Split System and Single Package	9.9 EER
	≥135,000 Btu/h and <240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.3 EER
		All Other	Split System and Single Package	9.1 EER
Heat Pumps, Air Cooled (Heating Mode)	≥65,000 Btu/h and <135,000 Btu/h (Cooling Capacity)	-	47°F db/43°F wb Outdoor Air	3.2 COP
			17°F db/15°F wb Outdoor Air	2.2 COP
	≥135,000 Btu/h (Cooling Capacity)	-	47°F db/43°F wb Outdoor Air	3.1 COP
			17°F db/15°F wb Outdoor Air	2.0 COP

For commercial unitary air conditioners, such baseline equipment is typically “lower-cost” units that contain no premium features, e.g., noise reduction, service, or appearance features. To determine the characteristics of the baseline unit in this screening analysis, the Department gathered information from trade organizations, manufacturers, and consultants with expertise in specific equipment types. The engineering analysis considered only single package equipment with gas heat in the estimate of the cost/efficiency relationship for the equipment classes under consideration. The Department chose to analyze equipment with gas heat, rather than air conditioning-only or electric heat, because the gas-heated units represent a large part of the market. The Department conducted the detailed engineering and energy savings analyses for selected single package units with capacities in the middle of the above ranges— namely, units with capacity of 90,000 Btu/h (or 7.5 tons) for the ≥65,000 to <135,000 Btu/h range; and units with capacity of 180,000 Btu/h (or 15 tons) for the ≥135,000 to <240,000 Btu/h range. Although DOE did not explicitly analyze split systems in the engineering analysis, it estimated that the results of the single package analysis apply to the split systems, and that the systems have equivalent cost/efficiency relationships. Chapter 5 provides a complete description of baseline commercial unitary air conditioners.

2.5.2 Cost-Assessment Approach

The Department, in consultation with stakeholders, used a cost assessment approach and supplemented the data with a design/option analysis to develop incremental cost/efficiency curves for the two representative capacities described above. The reverse engineering analysis relied on creating bills of materials for a sample of existing equipment that uses R-22 refrigerant. The Department developed the bills of materials through the reverse engineering either of physical teardowns or catalog teardowns. The Department then entered the bills of materials into a cost model that it used to estimate a manufacturer's cost for each piece of equipment. The Department then aggregated the costs of the equipment and their associated efficiencies and fit them to a curve to represent the cost/efficiency behavior of the industry. In addition, the Department derived confidence intervals that described the accuracy of the curve based on the variability of the manufacturer's costs.

2.5.3 Supplemental Design/Option Analysis

The Department used the design/option analysis to validate the accuracy of the cost/efficiency curves between 11.5 and 12.0 EER, where there are no existing equipment data points, by using the aforementioned cost model and a performance model to simulate equipment at higher efficiency levels.

2.5.4 Alternative Refrigerant Analysis

The last step in the process was the alternative refrigerant analysis that compared the cost/efficiency behavior of commercial unitary air-conditioning equipment using R-410a refrigerant to the R-22 refrigerant cost/efficiency curve by using the aforementioned cost model and the performance model to simulate R-410a equipment.

2.6 BUILDING ENERGY USE AND END-USE LOAD CHARACTERIZATION

The building energy use and end-use load characterization analysis produced energy use estimates and end-use load shapes for unitary air conditioners installed in a variety of commercial building types. The energy use estimates enabled DOE to evaluate energy savings from the operation of commercial unitary cooling equipment at various efficiency levels, while the end-use load shapes allowed DOE to evaluate the impact on electric demand from the operation of the cooling equipment. The analysis assumed a variety of building types in multiple climate locations to capture some of the diversity in usage, as well as the diversity of energy and the demand impact of the cooling equipment.

The 1995 Commercial Buildings Energy Consumption Survey (CBECS 95) was the primary source of data used to develop the representative building types and energy load shape characteristics for this analysis. Out of the CBECS 95 data, DOE selected a subset of six representative building types that included most of the top eight energy-using building types in the commercial sector. Further, the Department screened the individual CBECS buildings within those six representative building types to include in the representative building set only buildings with 70 percent or more total floor space being cooled by unitary air conditioning equipment. The threshold of 70 percent cooled floor space was based on keeping the sample size reasonable, yet still representative of the building types using unitary air conditioning equipment.

The Department modeled each CBECS sample building using the Building Loads and System Thermodynamics (BLAST) software. The Department computed each building's load by simulating a prototypical three-story, 48,000 square-foot building with five thermal zones per floor and with schedule and envelope characteristics chosen to represent each building sampled. The Department used the ventilation requirements of ASHRAE Standard 62.1-1999 as the basis for the ventilation rates in the building simulations. The Department then scaled the results of that prototype's simulation to match the specific geometry of the CBECS building being represented, including conditioned floor area, aspect ratio, number of floors, and number of thermal zones per floor. The Department simulated the buildings with equipment at ten different EER levels to determine the annual energy impacts of changes in EER.

2.7 EQUIPMENT PRICES

To carry out the LCC calculations, DOE needed to determine the cost to the customer of a baseline air conditioning unit and the cost of more efficient units. The customer price of such units is not generally known. By applying a multiplier called a "markup" to the manufacturer's prices that DOE derived, DOE estimated customer prices both for baseline and more efficient equipment.

Based on manufacturer input, the Department defined two types of distribution channels to describe how the equipment passes from the manufacturer to the customer. In the first distribution channel, the manufacturer sells the equipment to a wholesaler, who in turn sells it to a mechanical contractor, who in turn sells it (and its installation) to a general contractor, who in turn sells it to the customer. In the second distribution channel, the manufacturer sells the equipment directly to the customer through a national account. The Department further subdivided the first distribution channel by mechanical contractor size (as measured in annual revenues).

For each of the markups, DOE further differentiated between a baseline markup and an incremental markup. The Department defines baseline markups as coefficients that relate the manufacturer price of baseline equipment to the wholesale or contractor sales price of such equipment. Incremental markups are coefficients that relate changes in the manufacturer price of baseline equipment to changes in the wholesale or contractor sales price.

Equipment bought through national accounts is an exception to the usual distribution of heating, ventilating and air conditioning (HVAC) equipment to end users. Large customers of HVAC equipment, such as national retail chains, use national accounts to circumvent the typical chain of distribution. Due to the large volume of equipment purchased, large customers are able to buy equipment directly from the manufacturer at significantly lower prices than could be obtained through the typical distribution chain. The Department derived a "national account" markup by assuming that the resulting equipment price increase was one half of that realized from a typical chain of distribution.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

When DOE is determining the economic justification for its standards, EPCA directs the Department to consider several different factors, including the economic impact of potential standards on consumers. (42 U.S.C. 6313(a)(6)(B)(i)) To address these provisions, the Department calculated changes in LCCs to customers that would likely result from a proposed standard, as well as a distribution of PBPs. The effects of standards on individual consumers include changes in operating expenses (usually lower) and changes in total installed cost (usually higher). The Department analyzed the net effect by calculating the change in LCC as compared to the base case. The Department determined the base case manufacturing price in the engineering analysis. The LCC calculation considers total installed cost (equipment purchase price plus installation cost), operating expenses (energy, repair, and maintenance costs), appliance lifetime, and discount rate. The Department performed the LCC analysis from the perspective of the user of the equipment.

At this ANOPR stage, the Department generated LCC and PBP results as probability distributions using a mathematical simulation based on Monte Carlo methods, in which inputs to the analysis consisted of probability distributions rather than single-point values. As a result, the Monte Carlo analysis produced a range of LCC and PBP results. A distinct advantage of this type of approach is that the Department can identify the percentage of users achieving LCC savings or attaining certain PBP values that would result from an increased efficiency standard, in addition to the average LCC savings or average PBP for that standard. Because DOE conducted the analysis in this way, it can express the uncertainties associated with the various input variables as probability distributions. During the post-ANOPR consumer analysis, the Department might evaluate additional parameters and prepare a comprehensive assessment of the economic impacts on sub-groups of users.

To make the analysis transparent, the Department calculated the LCC and the distribution of PBP using an LCC spreadsheet model developed in Microsoft Excel®. An add-in to Excel® called Crystal Ball® (a commercially available software program) allows for input variables to be characterized with probability distributions.

As mentioned above in the building energy use and end-use load characterization analysis, the whole-building simulation analysis generates building energy consumption data for each hour of a typical meteorological year. For each of the 1,033 records in the building sample, DOE disaggregated the hourly building energy consumption into the air conditioning energy consumption, the supply or ventilation fan energy consumption, and the energy consumption resulting from all other electric end-uses in the building. Because the supply fan is integral to the air conditioning equipment, DOE included energy consumption for ventilation, even during periods where mechanical cooling is not required, as part of the total air conditioning energy consumption.

The Department coupled the whole-building simulation data with electricity price data to generate an annual energy expense for air conditioning for each of the building records. The Department used two approaches to generate annual energy expense data: a tariff-based approach and an hourly based approach.

The tariff-based approach establishes an annual energy expense using electricity prices determined from electric utility tariffs collected in the year 2002. Under the tariff-based approach, the Department aggregated the hourly simulated energy consumption data into monthly energy consumption and peak demand values. It then coupled the monthly energy consumption and peak demand values with actual electric utility tariffs to calculate a monthly energy expense. It determined an annual energy expense by summing the monthly energy expenses.

The hourly based approach establishes an annual energy expense using electricity prices that may exist, assuming all electricity markets are deregulated. For electricity markets that are already deregulated, the Department collected actual wholesale hourly electricity prices. For markets that are still regulated, it collected hourly system load and generation cost data and then used it as a proxy for wholesale prices that might exist if the market were deregulated. Under the hourly based approach, the Department coupled the hourly, simulated energy consumption data directly with hourly electricity price data to calculate an annual energy expense.

For each efficiency level analyzed, the LCC analysis requires input data for the total installed cost and the operating cost of the equipment. The Department built up the total installed cost from the manufacturer prices estimated in the engineering analysis. As detailed in the discussion of equipment prices in that analysis, DOE applied markups to the manufacturer prices based on the type of distribution channel. The Department multiplied the baseline or standard-level manufacturer price by the appropriate overall markup to arrive at the price paid by the customer. It derived installation costs and added these costs to the customer equipment price to arrive at the total installed cost. The Department decided that data for 7.5-ton and 15-ton rooftop air conditioners are representative of installation costs for the ≥65,000 Btu/h and <135,000 Btu/h, and ≥135,000 Btu/h and <240,000 Btu/h air conditioner equipment classes, respectively.

The Department based the operating cost for the LCC analysis on energy consumption data developed from the whole-building simulations. The Department defined the operating cost as the sum of the energy expenditure associated with operating the equipment, the repair cost associated with component failure, and the cost for maintaining equipment operation.

The Department derived the discount rates for the commercial air conditioner analysis from estimates of the cost of capital of companies that buy commercial air conditioning equipment. The Department believes that this is the most accurate methodology for estimating discount rates for users of commercial unitary air conditioners. Most companies use both debt and equity capital to fund investments. Therefore, for most companies, the cost of capital is the weighted average of the cost to the firm of equity and debt financing.

The Department calculated the PBP based on the same inputs used for the LCC analysis (except that the PBP values were based only on the first year the standard takes affect). The output was a probability distribution of payback periods, including the mean and median payback period, as well as the minimum and maximum payback periods.

2.9 NATIONAL IMPACT ANALYSIS

The national impact analysis assesses the NPV of total customer LCC and national energy savings (NES). The Department determined both the NPV and NES for the efficiency levels considered for the two equipment classes of commercial unitary air conditioners: ≥65,000 Btu/h and <135,000 Btu/h, and ≥135,000 Btu/h and <240,000 Btu/h. To make the analysis more accessible and transparent to all stakeholders, the Department prepared an NES Spreadsheet Model in Microsoft Excel® to forecast energy savings and the national economic costs and savings resulting from new standards. Unlike the LCC analysis, the NES Spreadsheet Model does not use probability distributions for inputs or outputs. To assess the impact of input uncertainty on the NES and NPV results, the Department can conduct sensitivity analyses for future analyses by running scenarios on input variables that are of interest to stakeholders. The Department conducted an assessment of the aggregate economic impacts at the national level for this ANOPR.

2.9.1 National Energy Savings Analysis

The Department calculated the national energy consumption by multiplying the number of units, or stock, of commercial air conditioners (by vintage) by the unit energy consumption (also by vintage). Vintage represents the age of the equipment. The Department calculated national annual energy savings from the difference between national energy consumption in the base case (without new standards) and in each standards case. The analysis included estimated energy savings by fuel type used for generating electricity. The Department estimated energy consumption and savings based on site energy, and then converted the electricity consumption and savings to source energy. Cumulative energy savings are the sum of the annual NES, which DOE determined over specified time periods.

The stock of commercial air conditioning equipment is dependent on annual shipments and the lifetime of the equipment. The Department conducted shipments projections under the base case and standards cases for a variety of possible equipment efficiency scenarios and equipment efficiency trends. The Department determined that shipment projections under the standards cases were lower than those from the base case projection, because of the higher installed cost of the more-efficient equipment. Higher installed costs caused some customers to forego equipment purchases. As a result, the Department used the standards case shipments projection and, in turn, the resulting stock of equipment under the standards case, to determine the NES. Calculating the NES in this way avoids the inclusion of savings resulting from displaced shipments.

Therefore, the inputs for the determination of NES are: (1) annual energy consumption per unit; (2) shipments; (3) equipment stock; (4) national energy consumption; and (5) site-to-source conversion factors.

2.9.2 Net Present Value Analysis

The Department calculated net savings each year as the difference between total operating cost savings (including electricity, repair, and maintenance cost savings) and increases in total installed costs (including equipment price and installation cost). The Department calculated savings over the life of the equipment, accounting for differences in yearly energy rates. The Department calculated NPV as the difference between the present value of operating cost savings and the present value of increased total installed costs. The Department discounted future costs and savings to the present with a discount factor.

The Department calculated increases in total installed costs as the product of the difference in the total installed cost between the base case and standards case and the annual sales volume or shipments in the standards case. Because costs of the more-efficient equipment bought in the standards case are higher than those of equipment bought in the base case, price increases appear as negative values in the NPV.

The Department expressed operating cost savings as decreases in operating costs associated with the higher energy efficiency of equipment bought in the standards case compared to the base case. Total operating cost savings are the product of savings per unit and the number of units of each vintage surviving in a particular year.

The inputs for the determination of NPV are: (1) total annual installed cost; (2) total annual operating cost savings; (3) discount factor; (4) present value of costs; and (5) present value of savings.

2.9.3 Efficiency Scenarios and Trends

Several of the inputs for the determination of NES (e.g., the annual energy consumption per unit) and NPV (e.g., the total annual installed cost and the total annual operating cost savings) are dependent upon the efficiency of the air conditioner. Thus, the Department developed base case and standards case efficiency trends. The efficiency trends specify the annual historical and forecasted shipment-weighted average equipment efficiencies.

The Department based historical shipment-weighted average efficiency trends for commercial air conditioners on a combination of limited commercial air conditioner efficiency data and residential central air conditioner efficiency trends. Once DOE established historical efficiency trends, it got future trends of equipment efficiency, and in turn, annual energy consumption by extrapolating from the historical trend.

The Department based its standards case forecasts (i.e., forecasts of efficiency trends after standards take effect) on the use of a roll-up efficiency scenario and parallel growth trend. Under a roll-up scenario, all equipment at efficiency levels below a prospective standard are moved or rolled-up to the minimum efficiency level allowed under the new standard. The distribution of equipment at efficiency levels above the prospective standards is unaffected (i.e., this equipment remains at its pre-standard efficiency levels). The roll-up efficiency scenario dictates how DOE determined efficiency distributions in the first year a new standard takes effect, but does not define how equipment efficiency will be distributed in the future. Under the parallel growth trend, the Department assumes that the standards case efficiency trend parallels the base case efficiency trend. In other words, the initial jump in shipment-weighted efficiency that occurs when the standard first becomes effective is maintained throughout the forecast.

2.9.4 Shipments Analysis

The Department chose an accounting model method to prepare shipment scenarios for the baseline and the various standards levels considered for commercial air conditioners. The model tracks the stocks and purchases of equipment in the two equipment classes of commercial air conditioners. Events and customer decisions influence how equipment is bought for new construction and replacement units. The Department modeled those decisions that are economically influenced with econometric equations.

The model is organized into three classes of elements: (1) stocks; (2) events; and (3) decisions. Stocks of commercial air conditioners are divided into ownership categories, and units are assigned to age categories. Events are things that happen to stocks independent of economic conditions, i.e., breakdowns requiring repair or replacement. Decisions are customer reactions to market conditions, e.g., whether to repair or replace equipment, or purchase an air conditioner for a building that does not have one. Customer purchase decisions are categorized by market segments. Decision trees are used to describe customer choices for purchases and repairs. A logit probability model simulates customer purchase decisions that are based on equipment price, operating costs, and business income level.

The Department calibrated the shipments model to historical shipments data. The Department extracted and documented information related to equipment shipments by domestic manufacturers from the U.S. Census Bureau *Current Industrial Reports*. Cooling capacity ranges in the U.S. Census Bureau data are expressed in a slightly different way than in this DOE rulemaking. The major classifications presented in the U.S. Census Bureau data for single and split system air conditioners are for ≥65,000 Btu/h and <135,000 Btu/h, and ≥135,000 Btu/h and <250,000 Btu/h. For heat pumps, the U.S. Census Bureau data list shipments for capacities greater than 65,000 Btu/h. Using the calibrated model, DOE forecasted shipments for the base case and all standards cases.

2.10 LIFE-CYCLE COST SUB-GROUP ANALYSIS

The LCC sub-group analysis evaluates economic impacts on virtually any group of customers, for example, customers of different business types who might be adversely affected by any change in the national energy efficiency standards levels for commercial unitary air conditioners. The Department intends to evaluate the impacts of particular sub-groups of customers in part by analyzing the LCC and PBP for these particular customers.

The Department intends to evaluate variations both in regional energy prices and use that might affect the NPV of an energy-efficiency standard to customer sub-groups. To the extent possible, the Department will get estimates of the variability of each input parameter and consider this variability in its calculation of customer impacts. Variations in energy use for a particular equipment type depend on factors such as climate, building type, and type of business. The Department intends to perform sensitivity analyses to consider how differences in energy use will affect various sub-groups of customers.

Thereafter, the Department will determine the impact on customer sub-groups using the LCC spreadsheet model. The spreadsheet model used for the LCC analysis can be used with different data inputs. The standard LCC analysis includes various commercial building types that use unitary air conditioners. Moreover, DOE can analyze the LCC for any sub-group, such as office buildings in the southern U.S., by using the LCC spreadsheet model and only sampling that sub-group. Details of this model are explained in the section describing the LCC and PBP Analyses.

The Department will be particularly sensitive to increases in the purchase price of commercial unitary air conditioners to avoid a negative economic impact on any identified customer sub-group, such as small businesses (i.e., those with low annual revenues) which might not be able to afford a significant increase in the price of unitary air conditioning equipment. The Department understands that increased first costs to customers resulting from energy-efficiency standards are especially important to smaller businesses, because this group is most sensitive to price increases. For these types of customers, increases in first costs for equipment could preclude the purchase of a new model unitary air conditioner. As a result, some customers might keep air conditioning equipment beyond its useful life. These older pieces of equipment are generally less efficient to begin with, and their efficiency may deteriorate if they are kept beyond their useful life. Also, increases in first cost could preclude the purchase and use of equipment altogether, resulting in a potentially large loss of utility.

Although business income and annual revenues are not known for the buildings analyzed in the LCC analysis, the floor space occupied by a business may be an indicator of its annual income. If this is generally true, the Department would be able to perform sub-group analyses on smaller businesses. If the Department determines that business income does not correlate with floor space, then the Department might not be able to perform sub-group analyses on smaller businesses. In this event, the Department will seek other sources of data to use to perform these analyses.

2.11 MANUFACTURER IMPACT ANALYSIS

The manufacturer impact analysis focuses on manufacturers of commercial unitary air conditioning. Potential impacts would include financial, quantitative, and qualitative effects that might result from new energy efficiency standards, and consequentially lead to changes in the manufacturing practices for air cooled, electrically operated unitary central air conditioning equipment for commercial applications. The Department will identify these potential impacts through interviews with manufacturers and other stakeholders.

The Department intends to conduct the manufacturer impact analysis in three phases. Phase One consists of two activities: prepare an industry characterization, and identify issues. Phase Two addresses the broader industry where the Department would use the Government Regulatory Impact Model (GRIM) to perform an industry cash flow analysis. In addition, Phase Two involves developing interview guidelines and a questionnaire for use in Phase Three. At the beginning of Phase Three, the Department will interview manufacturers and adjust the industry cash flow analysis as appropriate. Thereafter, Phase Three will entail additional cash flow analyses of the different sub-groups that could be affected by the rulemaking. Furthermore, Phase Three will examine any additional impacts on competition, manufacturing capacity, employment, and the cumulative burden of other regulations impacting manufacturers.

2.12 UTILITY IMPACT ANALYSIS

To estimate the effects of any proposed energy efficiency standards for commercial unitary air conditioners on the electric utility industry, the Department intends to use a variant of its National Energy Modeling System (NEMS).[a] NEMS is used by the Energy Information Administration (EIA) to produce the *2003 Annual Energy Outlook* (*AEO2003*). The Department will use a variant, known as NEMS-BT, to provide key inputs to the analysis and generate the impacts on the electric utility industry from proposed energy efficiency standards levels. When necessary, the Department will perform some exogenous calculations. Thus, the utility impact analysis is a comparison between NEMS-BT results for the base case and for policy cases in which proposed standards are in place. The intended results of the analysis would consist of forecasted differences between the base and standards cases for electricity generation, installed capacity, sales, and prices.

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[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is the *National Energy Modeling System: An Overview 2000*, DOE/EIA-0581(2000), March, 2000. The DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on DOE/EIA assumptions, DOE refers to it by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed). The model was previously named NEMS-BRS, after the Department's Office of Buildings Research and Standards.

In general, the use of NEMS-BT for the utility impact analysis offers several advantages. As the official DOE energy forecasting model, it relies on a set of assumptions that are transparent and have received wide exposure and commentary. The NEMS-BT allows an estimate of the interactions between the various energy supply and demand sectors and the economy as a whole. The utility impact analysis would report any changes in installed capacity and generation of electricity by fuel type which resulted from each trial energy-efficiency standard level, as well as changes in electricity sales to the commercial sector.

The Department conducts the utility impact analysis as a policy deviation from the *AEO2003*, applying the same basic set of assumptions. For example, the operating characteristics (e.g., energy conversion efficiency and emissions rates) of future electricity generating plants are as specified in the *AEO2003* reference case, as are the prospects for natural gas supply.

Also, the Department will explore deviations from some of the reference case assumptions corresponding to medium growth to represent alternative futures. Two such alternative scenarios use the high and low economic growth cases of *AEO2003*. The high economic growth case assumes higher projected growth rates for population, labor force, and labor productivity, resulting in lower predicted inflation and interest rates, and higher overall aggregate economic growth, relative to the reference case. The opposite is true for the low-growth case. While supply-side growth determinants are varied in these cases, *AEO2003* assumes the same reference case energy prices for all three economic growth cases. Different economic growth scenarios will affect the rate of growth of electricity demand.

For example, where NEMS provides reference case load shapes for several end uses by Census Bureau Division, including commercial space cooling, the Department would then use predicted growth in demand for each end use to build up a projection of the total electric system load growth for each region, which in turn would be used to predict any necessary additions to capacity. The NEMS-BT accounts for the implementation of efficiency standards by decrementing the appropriate reference case load shape. The Department would determine the size of the decrement using data for the per-unit energy savings developed in the LCC and PBP Analyses and the shipments forecast developed for the NES analysis.

2.13 ENVIRONMENTAL ASSESSMENT

The Department intends to conduct an assessment of the impacts of proposed commercial unitary air conditioner standards levels on certain environmental indicators, using NEMS-BT to provide key inputs to the assessment and generate the impacts. When necessary, the Department will perform some exogenous calculations. Results of the environmental assessment are similar to those provided in *AEO2003*.

The environmental assessment considers two pollutants, sulfur dioxide (SO_2) and nitrogen oxides (NO_x), and one emission, carbon (tracked in the NEMS-BT as carbon dioxide,

CO_2). For each of the energy-efficiency standards levels, the Department will calculate total emissions using NEMS-BT and external analyses as needed.

The Department intends to conduct the environmental assessment as a policy deviation from the *AEO2003*, applying the same basic set of assumptions. For example, the emissions characteristics of an electricity generating plant will be exactly those used in *AEO2003*. The Department's assessment will take into account any factors affecting the type of electricity generation and, in turn, the type and amount of airborne emissions being generated by the utility industry.

The results of the environmental assessment will be similar to a complete NEMS run as published in the *AEO2003*. These include power sector emissions for SO_2, NO_x, and carbon, and SO_2 prices, in five-year forecasted increments extrapolated to the year 2030. The Department will report the outcome of the assessment for each trial standard level as a deviation from the *AEO2003* reference cases.

2.14 EMPLOYMENT IMPACT ANALYSIS

The Department intends to estimate the impacts of energy-efficiency standards for commercial unitary air conditioners on employment for equipment manufacturers, relevant service industries, energy suppliers, and the economy in general. The Department will separate employment impacts into indirect and direct impacts. Direct employment impacts will result if standards lead to a change in the number of employees at manufacturing plants and related supply and service firms.

Indirect impacts are impacts on the national economy other than in the manufacturing sector being regulated. Indirect impacts might result both from expenditures shifting among goods (substitution effect), and changes in income, which could lead to a change in overall expenditure levels (income effect). The Department defines indirect employment impacts from energy-efficiency standards as net jobs eliminated or created in the general economy, as a result of increased spending on the purchase price of equipment and reduced customer spending on energy.

The Department believes that new commercial unitary air conditioner standards will increase the total installed cost of equipment. The Department expects the same standards to decrease energy consumption, and therefore to reduce customer expenditures for energy. Over time, the increased total installed cost would be paid back through energy savings. The savings in energy expenditures could then be spent on new commercial investment and other items. Using an input/output model of the U.S. economy, this analysis seeks to estimate the effects on different sectors and the net impact on jobs. The Department intends to estimate national impacts for major sectors of the U.S. economy in the NOPR. The Department intends to use public and commercially available data sources and software to estimate employment impacts.

The Department's Building Technologies Program developed a spreadsheet model, Impact of Building Energy Efficiency Programs (IMBUILD), which could be used to analyze indirect employment impacts. The IMBUILD is a special purpose version of the Impact Analysis for Planning (IMPLAN) national input-output model that specifically estimates the employment and income effects of building energy technologies. The IMPLAN was developed originally by the U.S. Forest Service in cooperation with the Federal Emergency Management Agency (FEMA) and the Bureau of Land Management (BLM) to assist the Forest Service in land and resource management planning. The IMBUILD is an economic analysis system that focuses on those sectors most relevant to buildings, and characterizes the interconnections among 35 sectors as national input-output matrices. The IMBUILD output includes employment, industry output, and wage income. The Department can introduce into IMBUILD changes in expenditures, due to appliance standards, as perturbations to existing economic flows, and thus estimate the resulting net national impact on jobs by sector.

2.15 REGULATORY IMPACT ANALYSIS

The Department intends to prepare a draft regulatory impact analysis pursuant to E.O. 12866, "Regulatory Planning and Review," which will be subject to review under the Executive Order by the Office of Information and Regulatory Affairs (OIRA) 58 FR 51735 (October 4, 1993).

As part of the regulatory impact analysis, the Department will identify and seek to mitigate the overlapping effects on manufacturers of new or revised DOE energy-efficiency standards and other regulatory actions affecting the same equipment. Through manufacturer interviews and literature searches, the Department will compile information on burdens from existing and impending regulations affecting commercial unitary air conditioners (e.g., hydrochlorofluorocarbon (HCFC) refrigerant phaseout) and other equipment (e.g., non-unitary commercial air conditioners).

The Department's NOPR will include a complete quantitative analysis of alternatives to the proposed energy conservation standards. The Department plans to use the NES Spreadsheet Model (as discussed earlier in the section on the national impact analysis) to calculate the NES and the NPV corresponding to specified alternatives to the proposed conservation standards.